Modeling Susceptibility to Subsurface Pesticide Migration on a Regional Scale

by

Laurie Morgan

Washington State Department of Ecology

Presented to the Water Quality Partnership

July 19, 2001

(Notes have been added to the slides for posting on the web site.)

State Pesticide Management Plan Vulnerability Assessment Pilot

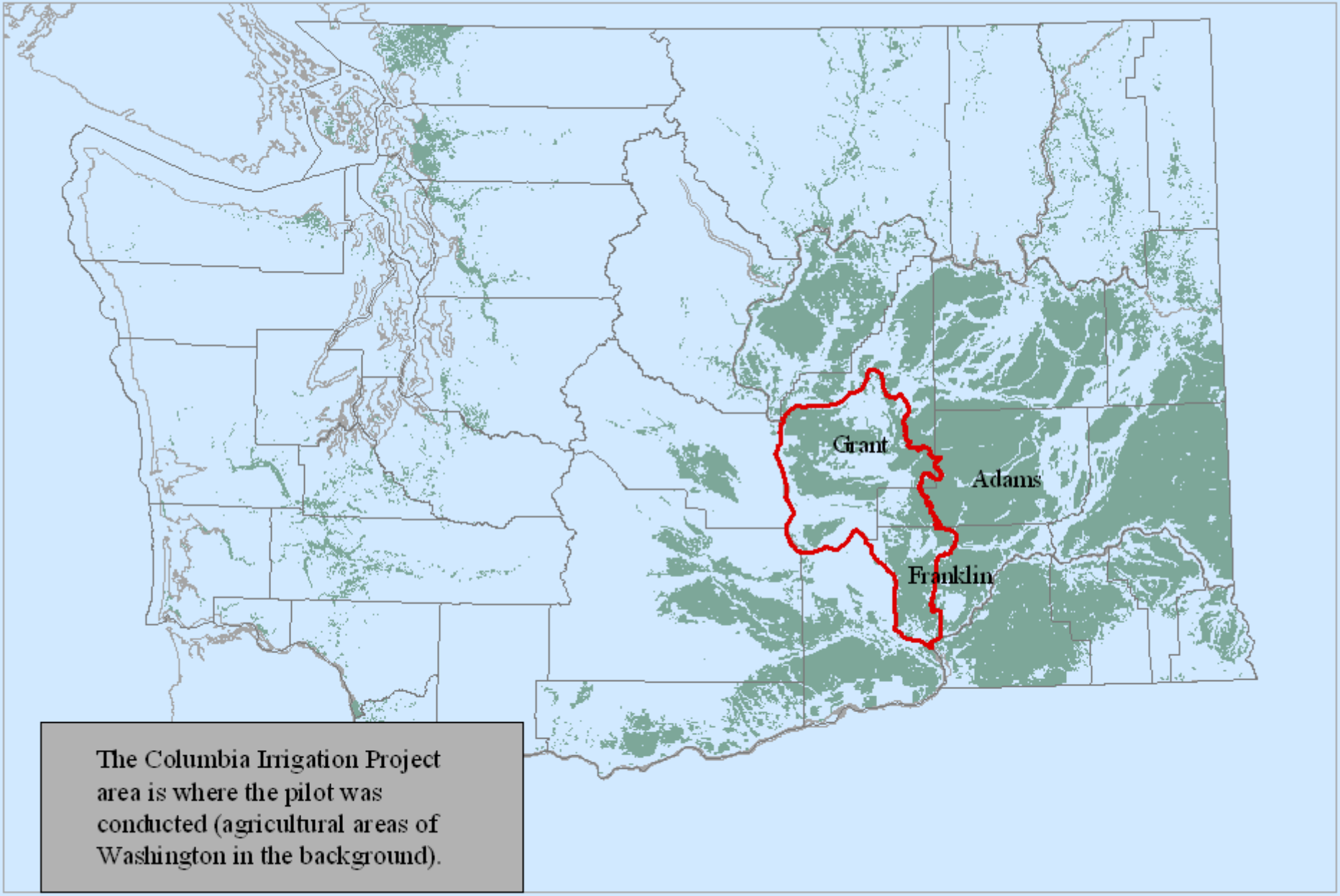
- Why we did this study
- A peek at the regional geologic processes that affect the Columbia Basin Irrigation Project area
- The PRZM model - inputs and results
- A few concluding remarks

Why we did this project...

- State Pesticide Management Plans must have a Vulnerability Assessment.
- On passage of the final rule, atrazine, simizine, alachlor, and metolachlor would be banned, unless a state had an EPA approved State Pesticide Management Plan.

Purpose of the Project

Evaluate the feasibility of using PRZM to help delineate areas regionally that are sensitive to risk of pesticide migration to groundwater.



The Columbia Irrigation Project area is where the pilot was conducted (agricultural areas of Washington in the background).

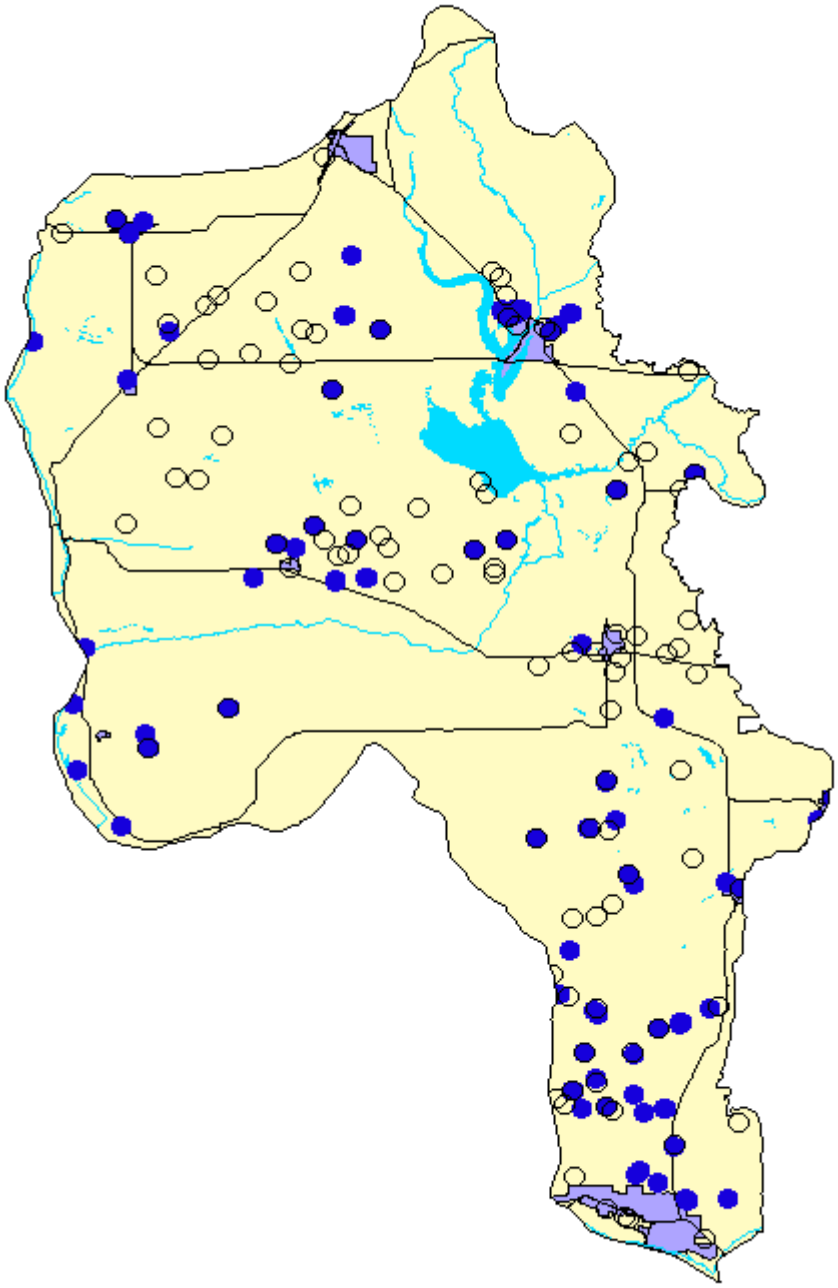
USGS NAWQA Data

- **Atrazine or DEA Detected**
  Atrazine from 0.001 to 0.97 ppb
  DEA from 0.001 to 0.18 ppb
- **Atrazine or DEA Not Detected**

NAWQA = National Water Quality Assessment

DEA = Desethylatrazine, a breakdown product of atrazine.

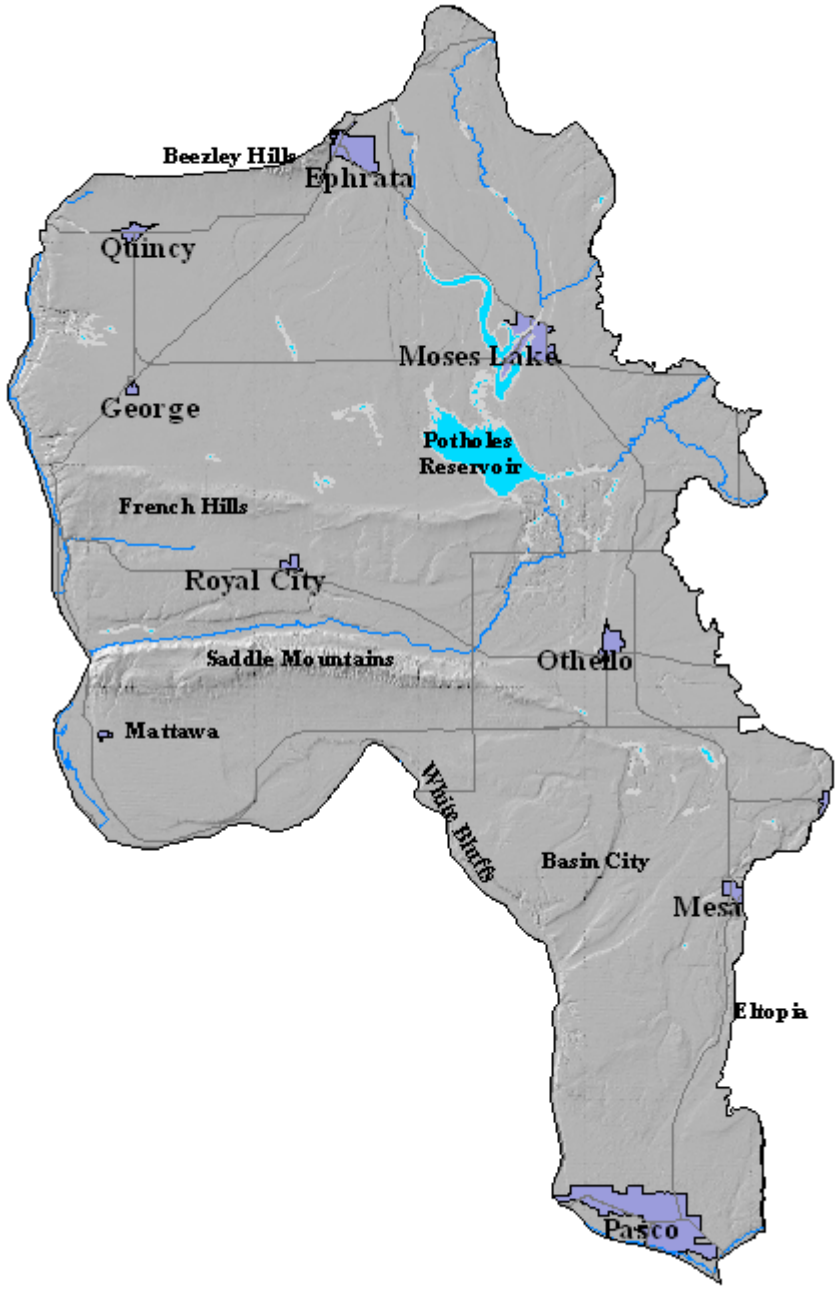
The USGS NAWQA study detected atrazine or desethylatrazine in wells all over the Columbia Basin Irrigation Project area, but never at any more than 1 part per billion. The EPA Maximum Contaminant Level for drinking water is 3 parts per billion.

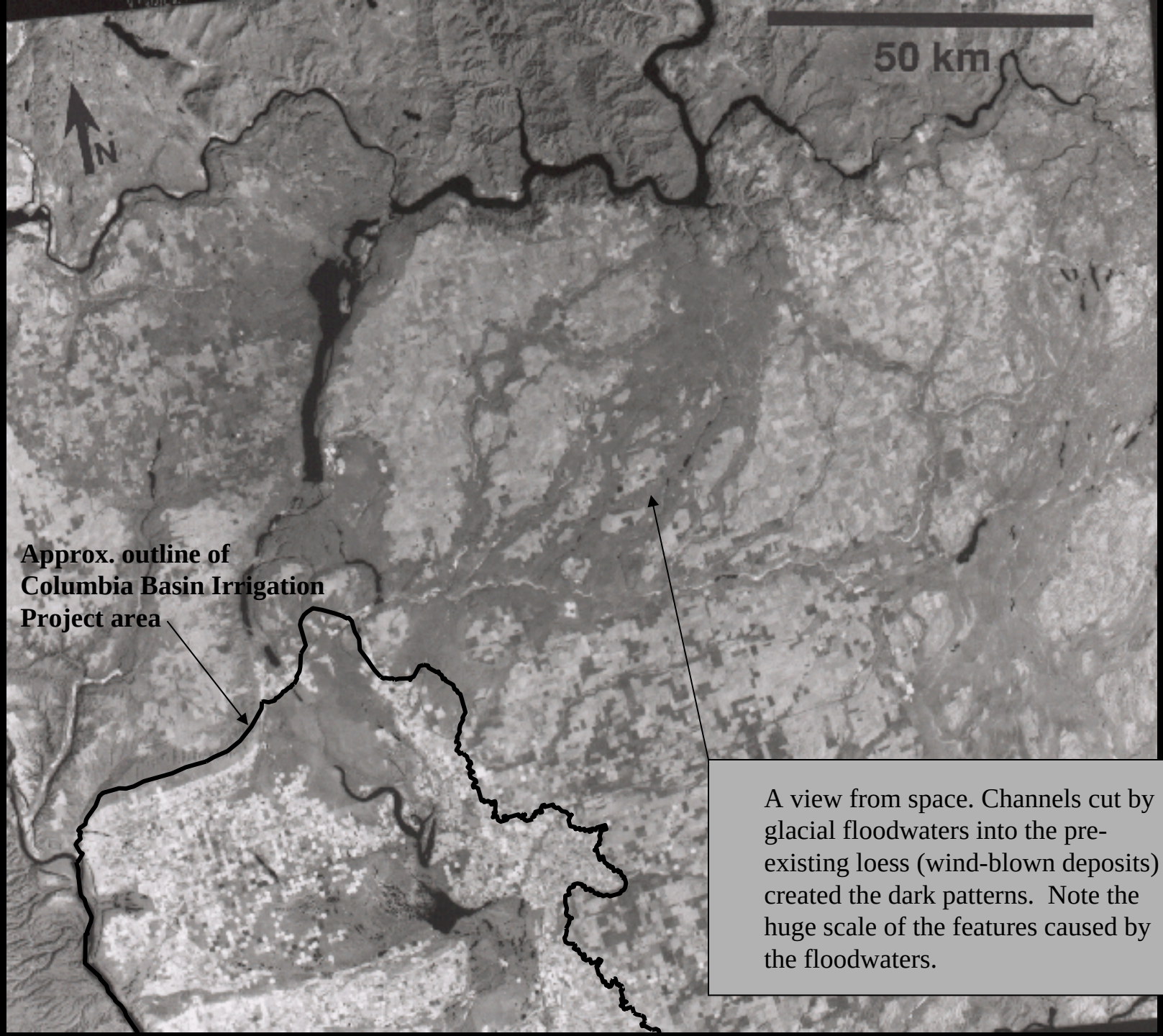


Next: A peek at the regional geologic processes that affect the Columbia Basin Irrigation Project area

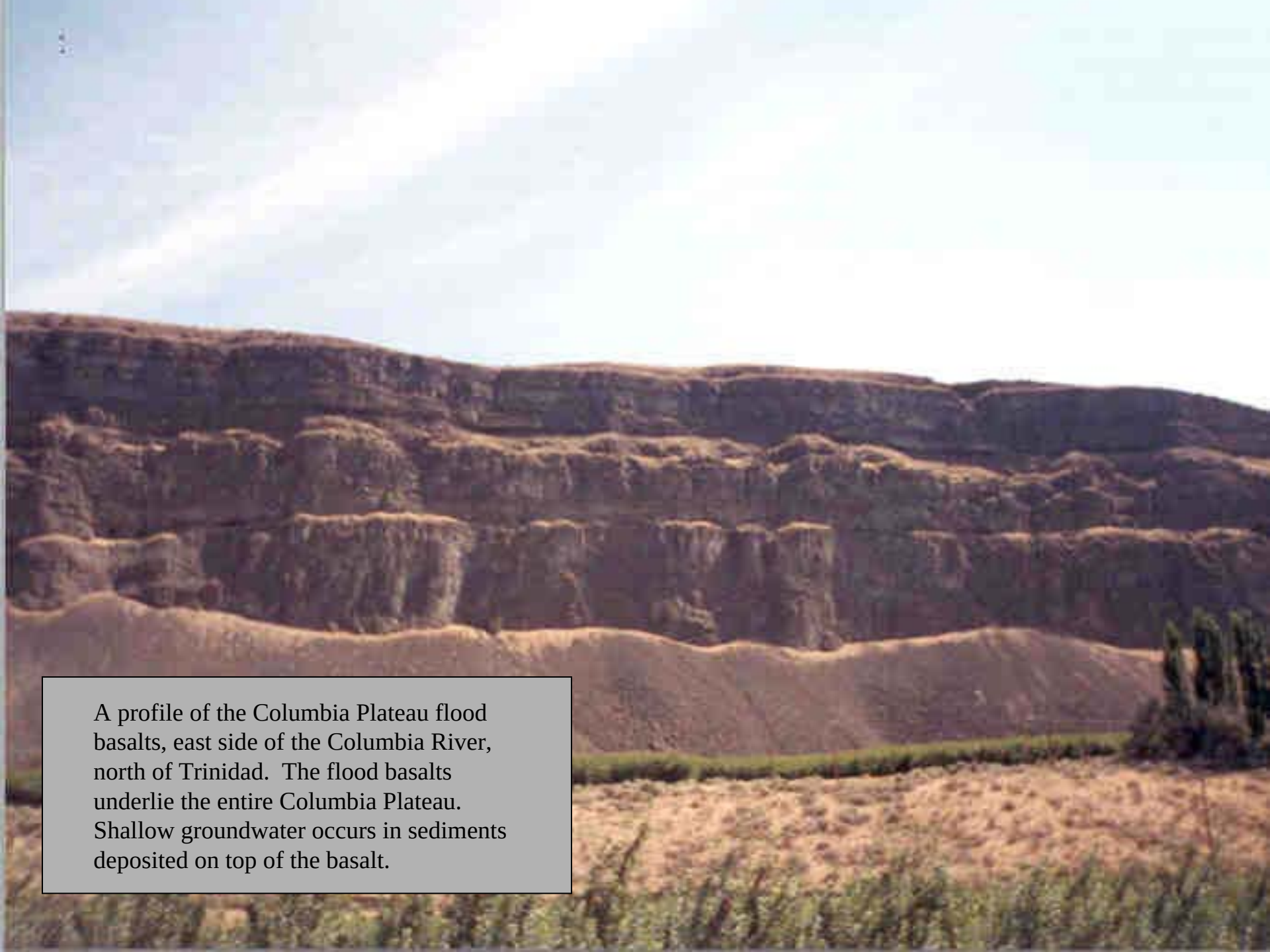
Geography of the Columbia Basin Irrigation Project Area.

In the next several slides, we will look at the large-scale geologic processes that create landscape patterns. The soils that derive their existence from geologic materials also follow landscape patterns. We will see the effect of these patterns on the soil susceptibility map later in the slide show, so it's a good idea to get a feel for how the landscape formed and the scale of these processes.

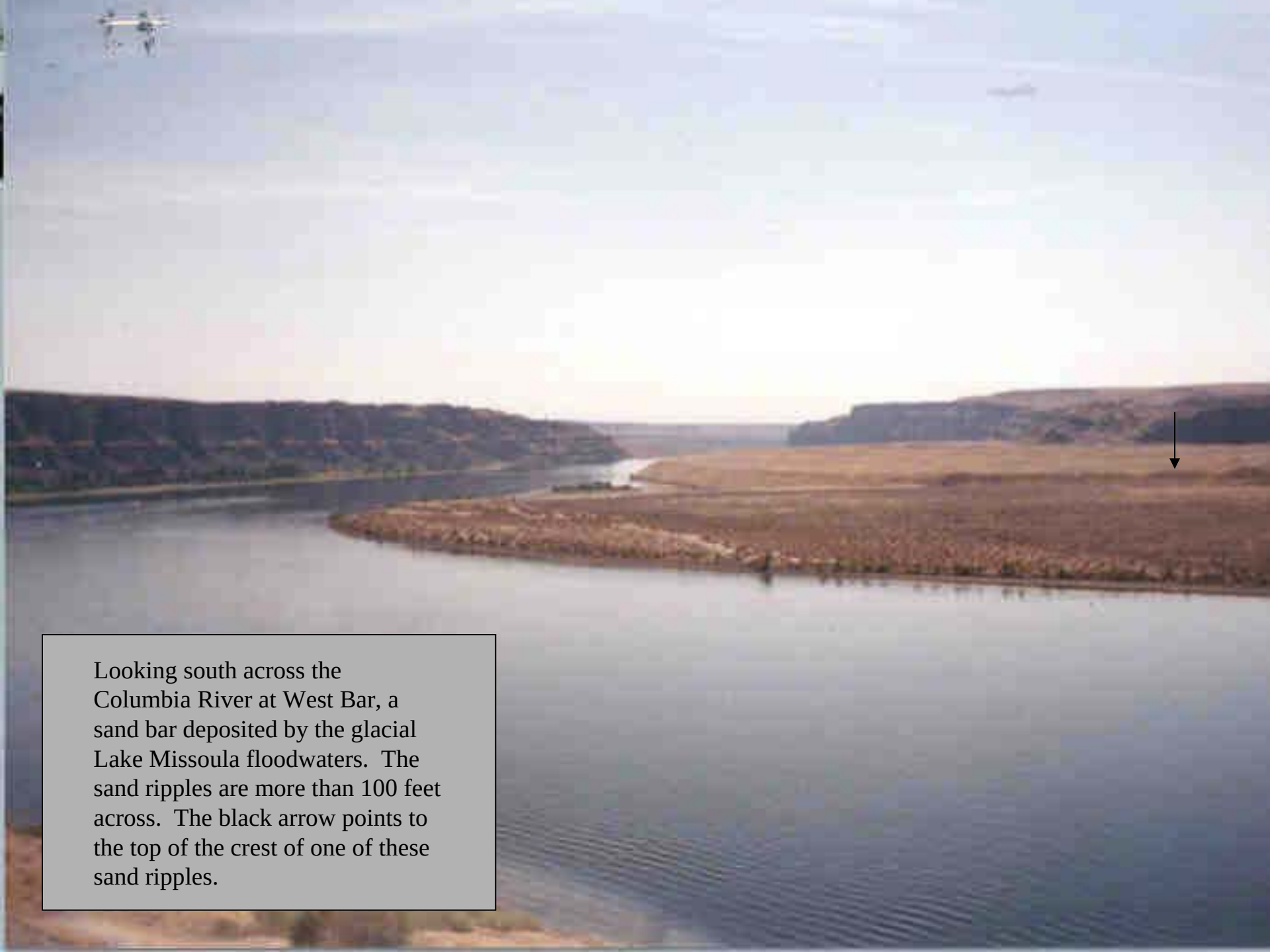




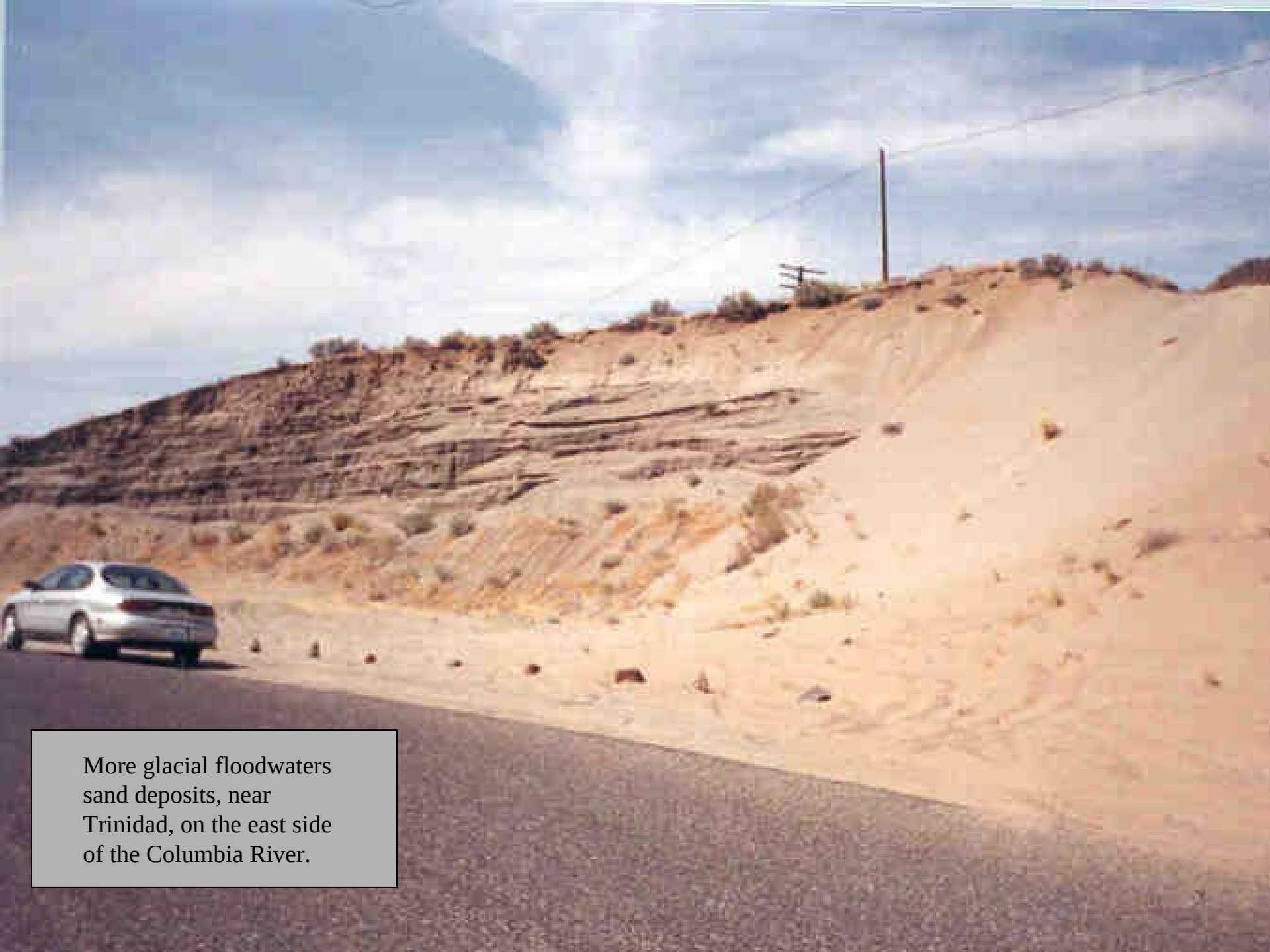
A view from space. Channels cut by glacial floodwaters into the pre-existing loess (wind-blown deposits) created the dark patterns. Note the huge scale of the features caused by the floodwaters.



A profile of the Columbia Plateau flood basalts, east side of the Columbia River, north of Trinidad. The flood basalts underlie the entire Columbia Plateau. Shallow groundwater occurs in sediments deposited on top of the basalt.



Looking south across the Columbia River at West Bar, a sand bar deposited by the glacial Lake Missoula floodwaters. The sand ripples are more than 100 feet across. The black arrow points to the top of the crest of one of these sand ripples.



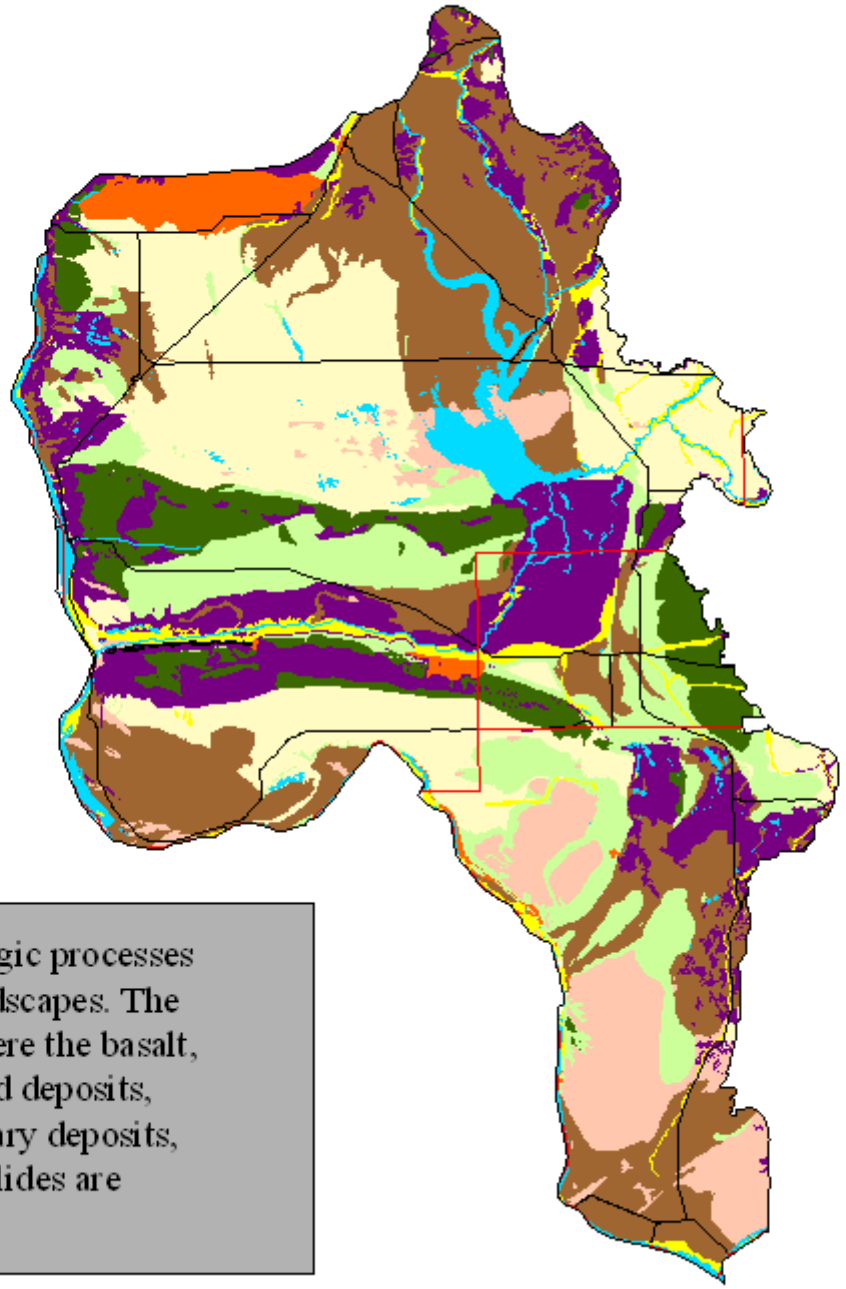
More glacial floodwaters sand deposits, near Trinidad, on the east side of the Columbia River.

Close-up of glacial floodwaters sand deposits, near Trinidad, on the east side of the Columbia River.

Gravel and cobbles deposited by the glacial floodwaters, north side of Moses Lake.

Gravel mine near previous photo,
north side of Moses Lake.

Channeled Scabland south of Othello. The ground was denuded down to the basalt by the powerful glacial floodwaters.



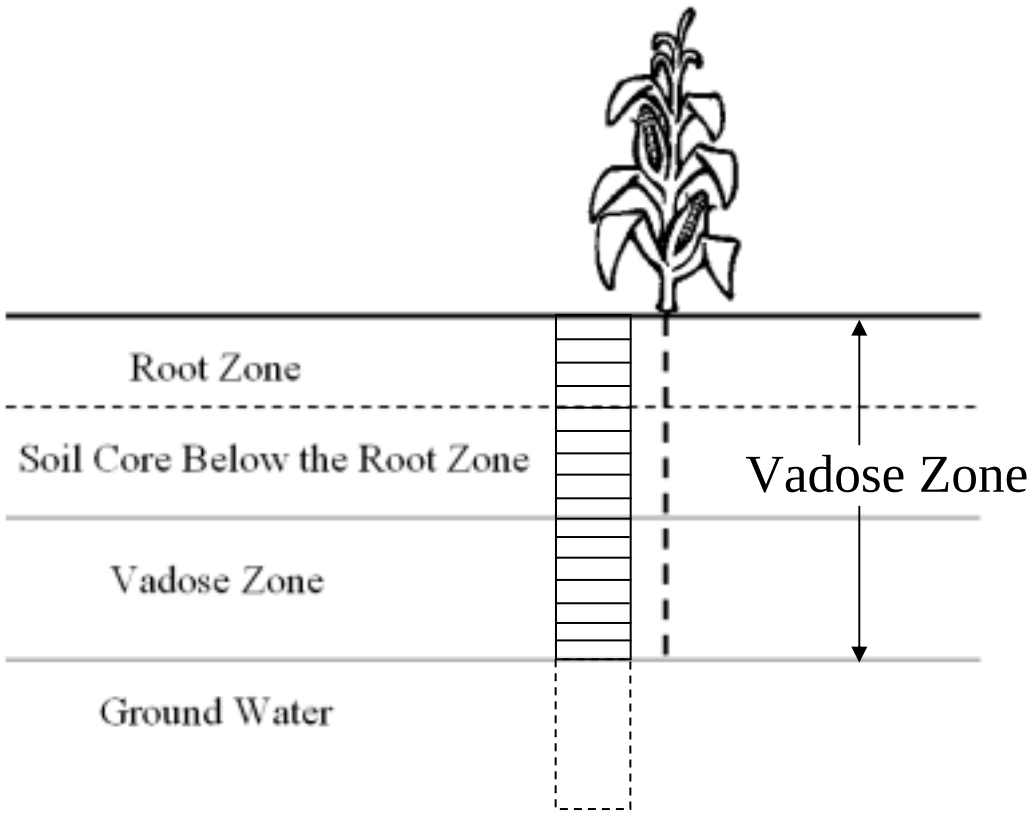
Surficial Geology

- Basalt
- Ringold formation
- Alluvium
- Dune sands
- Flood gravels
- Flood sands and silts
- Loess
- Landslides
- Water

Regional geologic processes formed the landscapes. The map shows where the basalt, the glacial flood deposits, older sedimentary deposits, loess and landslides are located.

Next: What goes in and what comes out of the PRZM model

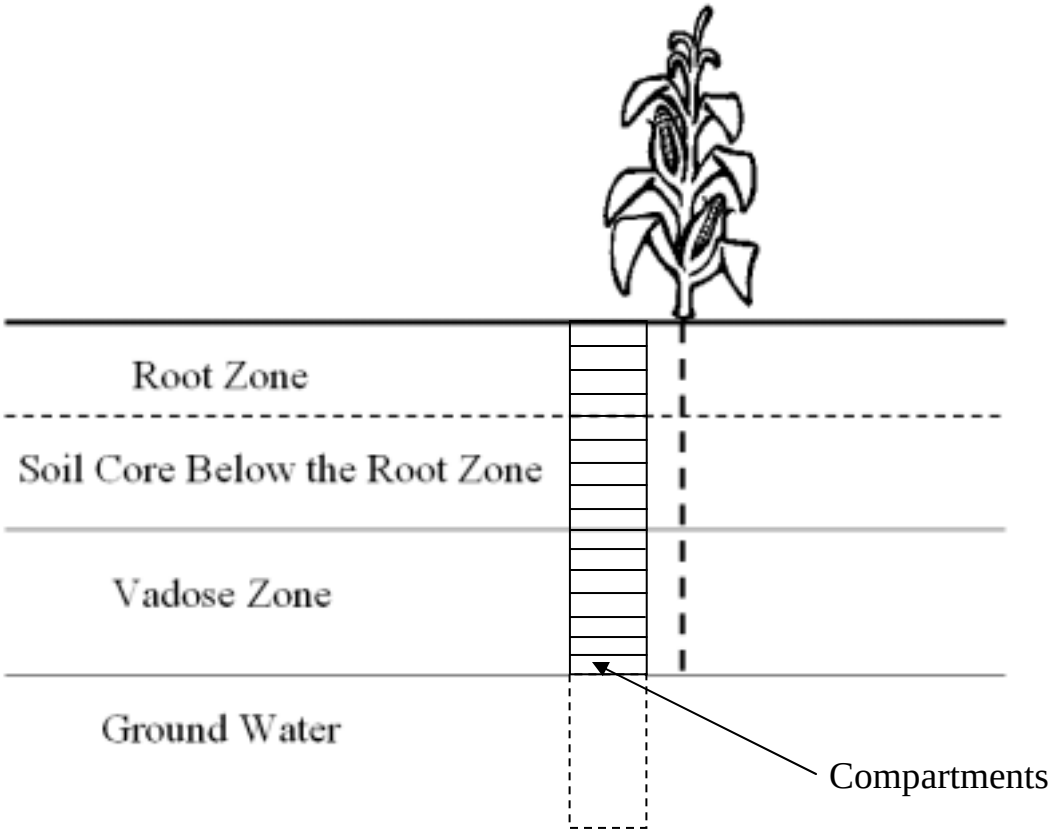
Pesticide **R**oot **Z**one **M**odel



Usually when you hear the term "Vadose Zone" it refers to the entire subsurface between the top of the ground to the top of the water table.

Pesticide **R**oot **Z**one **M**odel

The PRZM model divides the subsurface into the top soil profile, and the vadose zone below the soil profile.



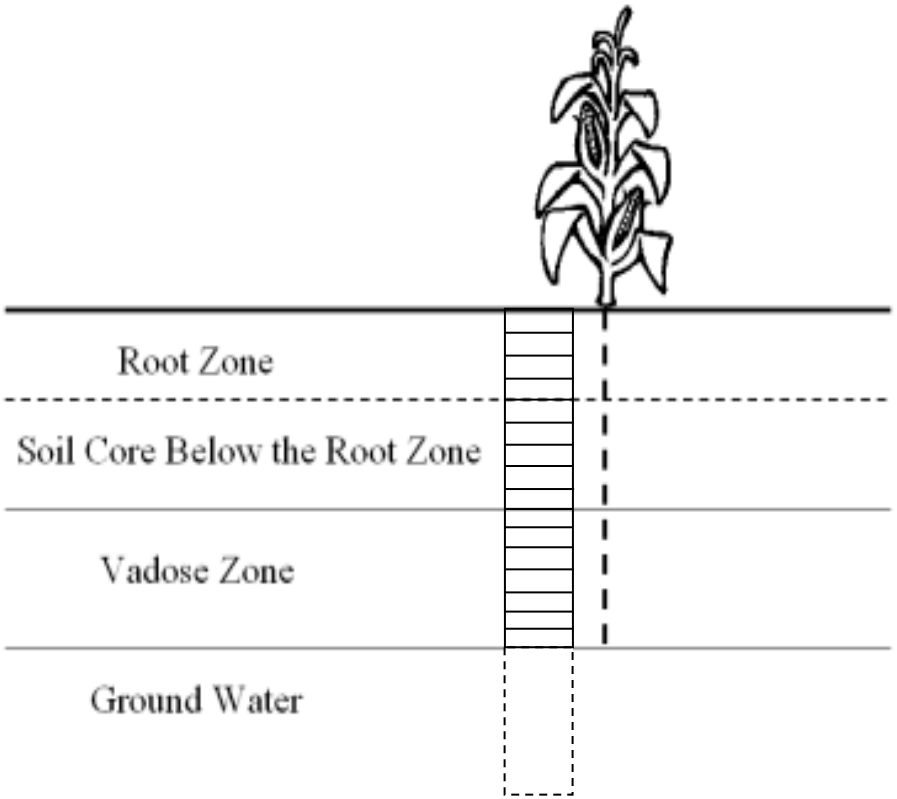
The entire depth is divided into compartments so the model can track calculations and results with depth.

Pesticide **R**oot **Z**one **M**odel

PRZM

VADOFT

AT123D



The “PRZM” part of the PRZM model is applied to the root zone and can be applied further to the soil below the root zone.

The “VADOFT” part of the PRZM model is applied to the vadose zone below the soil profile.

Another model, such as AT123D would need to be applied to the ground water zone itself.

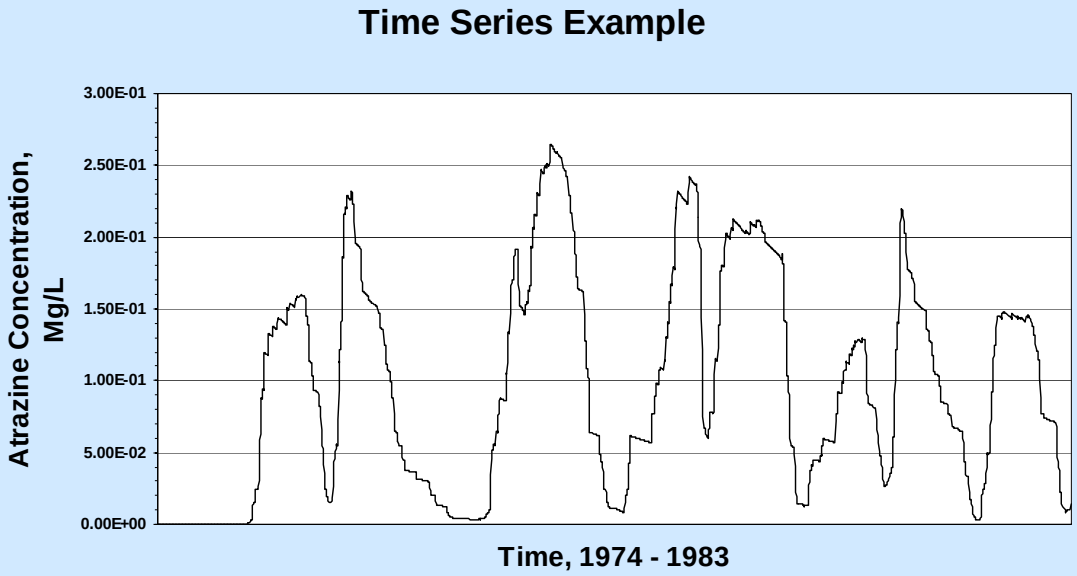
PRZM Model Inputs

- Meteorological
- Irrigation
- Soil
- Crop
- Pesticide

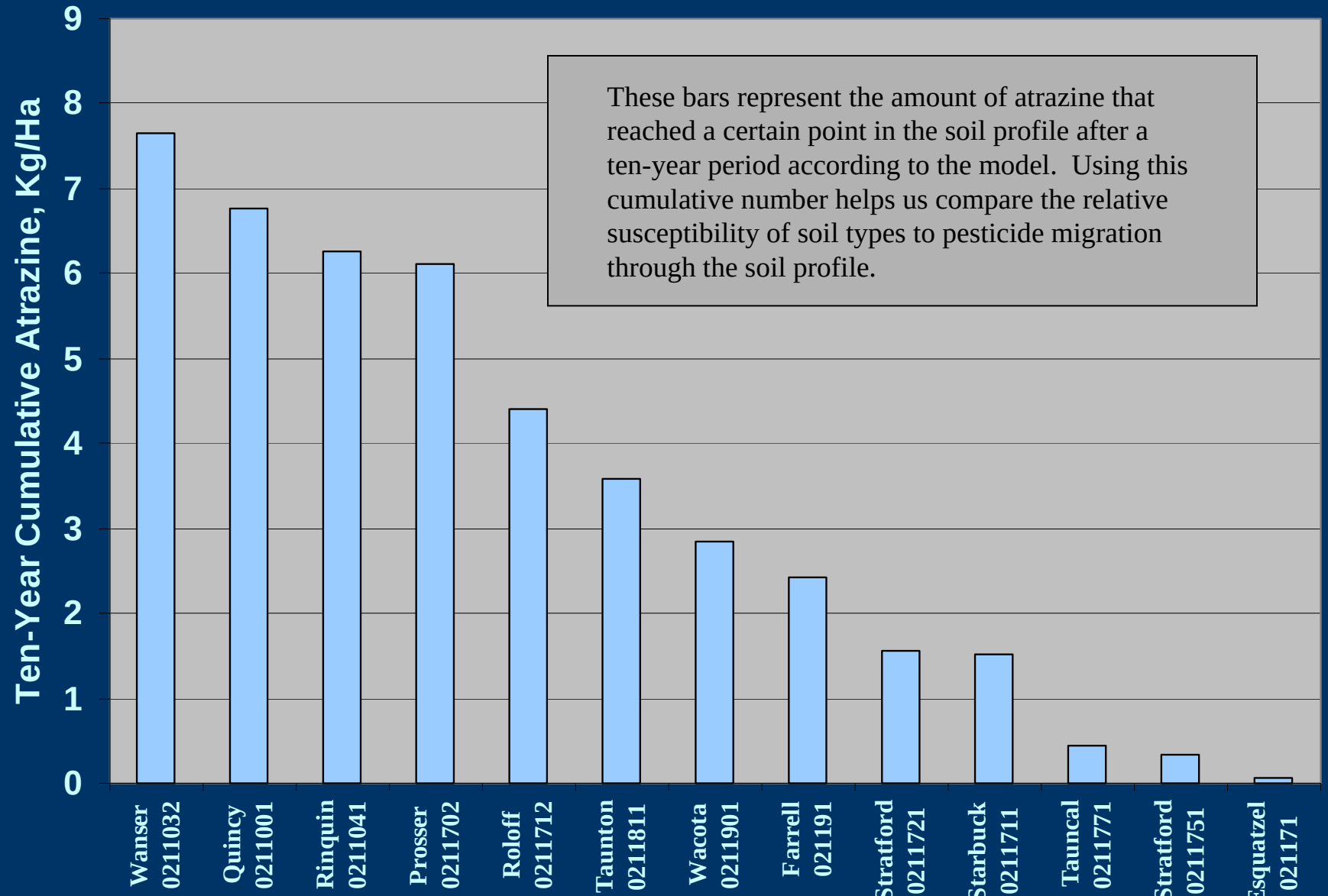
The PRZM Model takes inputs like daily rainfall, evapotranspiration, temperature, irrigation, soil properties, crop characteristics, and pesticide chemical properties into account and tracks how much pesticide and how much water travels down through the compartments on a daily basis. The run period we used was ten-years.

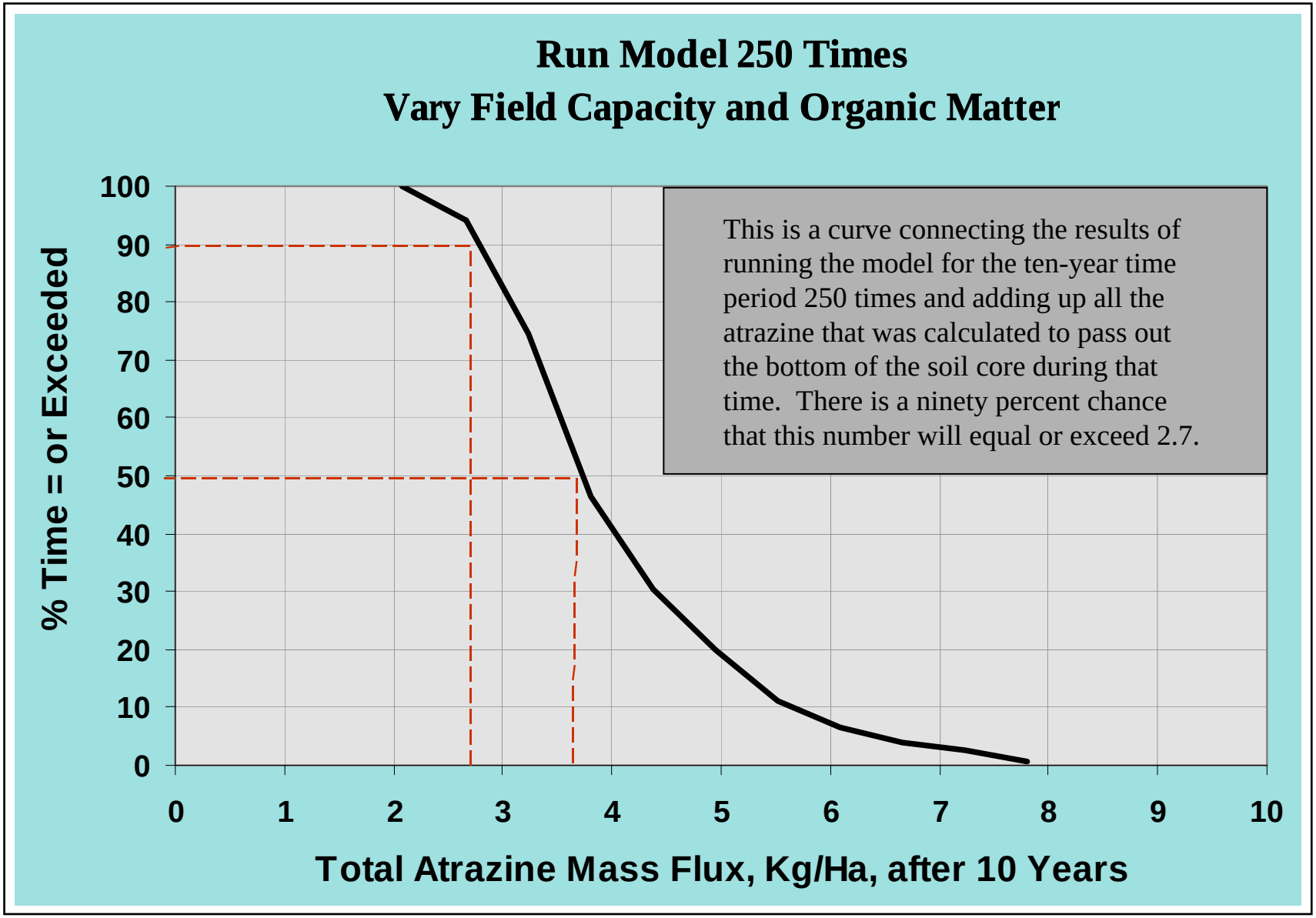
PRZM Model Outputs

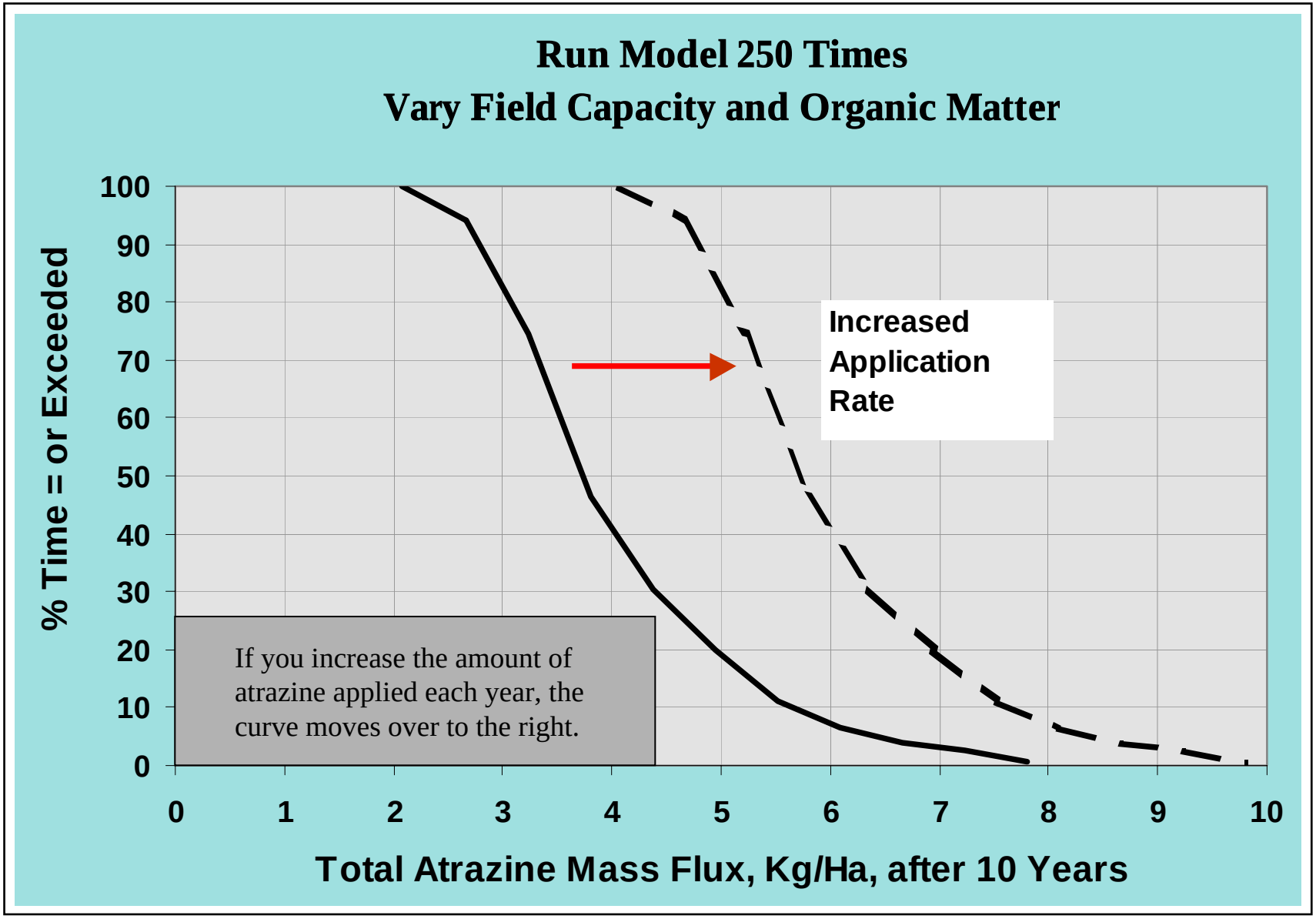
The amount of pesticide and the amount of water at any given time, at any depth of interest in the soil profile. Remember that this only represents the hypothetical amount given the model inputs!

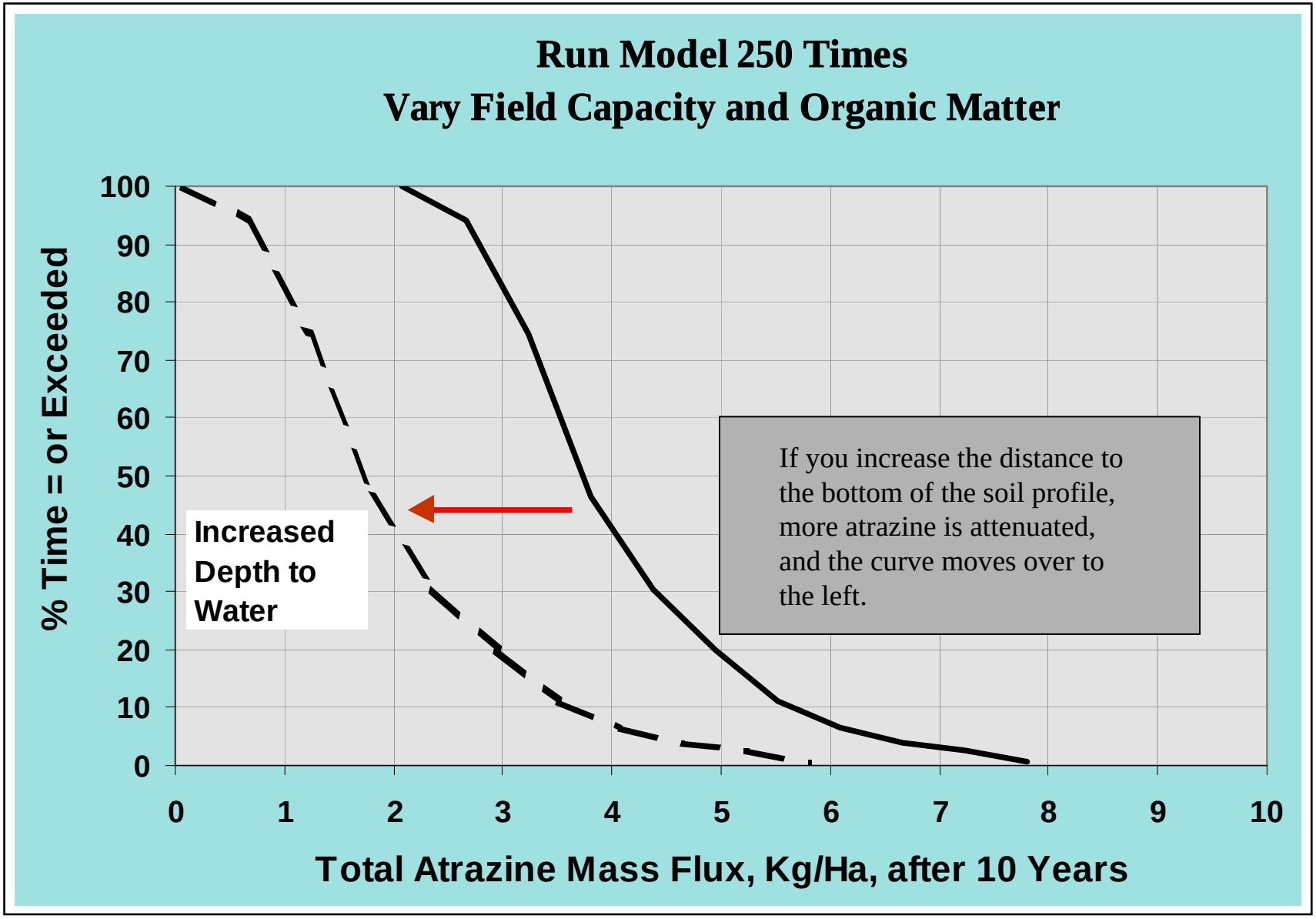


One Way to Compare Soil Types




Run Model 250 Times
Vary Field Capacity and Organic Matter
% Time = or Exceeded
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
Total Atrazine Mass Flux, Kg/Ha, after 10 Years
This is a curve connecting the results of running the model for the ten-year time period 250 times and adding up all the atrazine that was calculated to pass out the bottom of the soil core during that time. There is a ninety percent chance that this number will equal or exceed 2.7.


Run Model 250 Times
Vary Field Capacity and Organic Matter
% Time = or Exceeded
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
Total Atrazine Mass Flux, Kg/Ha, after 10 Years
Increased Application Rate
If you increase the amount of atrazine applied each year, the curve moves over to the right.

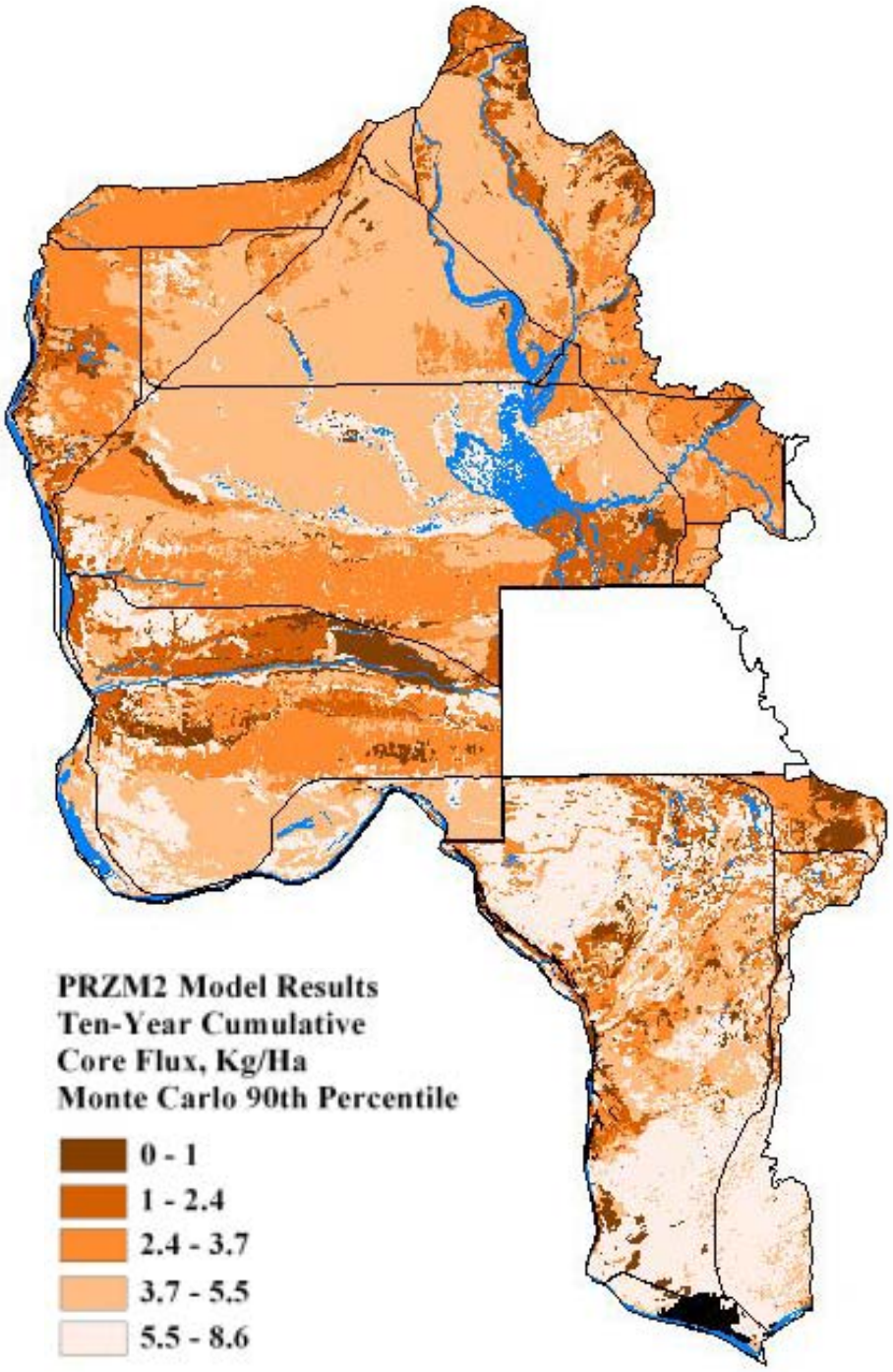

Run Model 250 Times
Vary Field Capacity and Organic Matter
% Time = or Exceeded
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
Total Atrazine Mass Flux, Kg/Ha, after 10 Years
Increased Depth to Water
If you increase the distance to the bottom of the soil profile, more atrazine is attenuated, and the curve moves over to the left.

Next: Applying the PRZM model results to a map using GIS

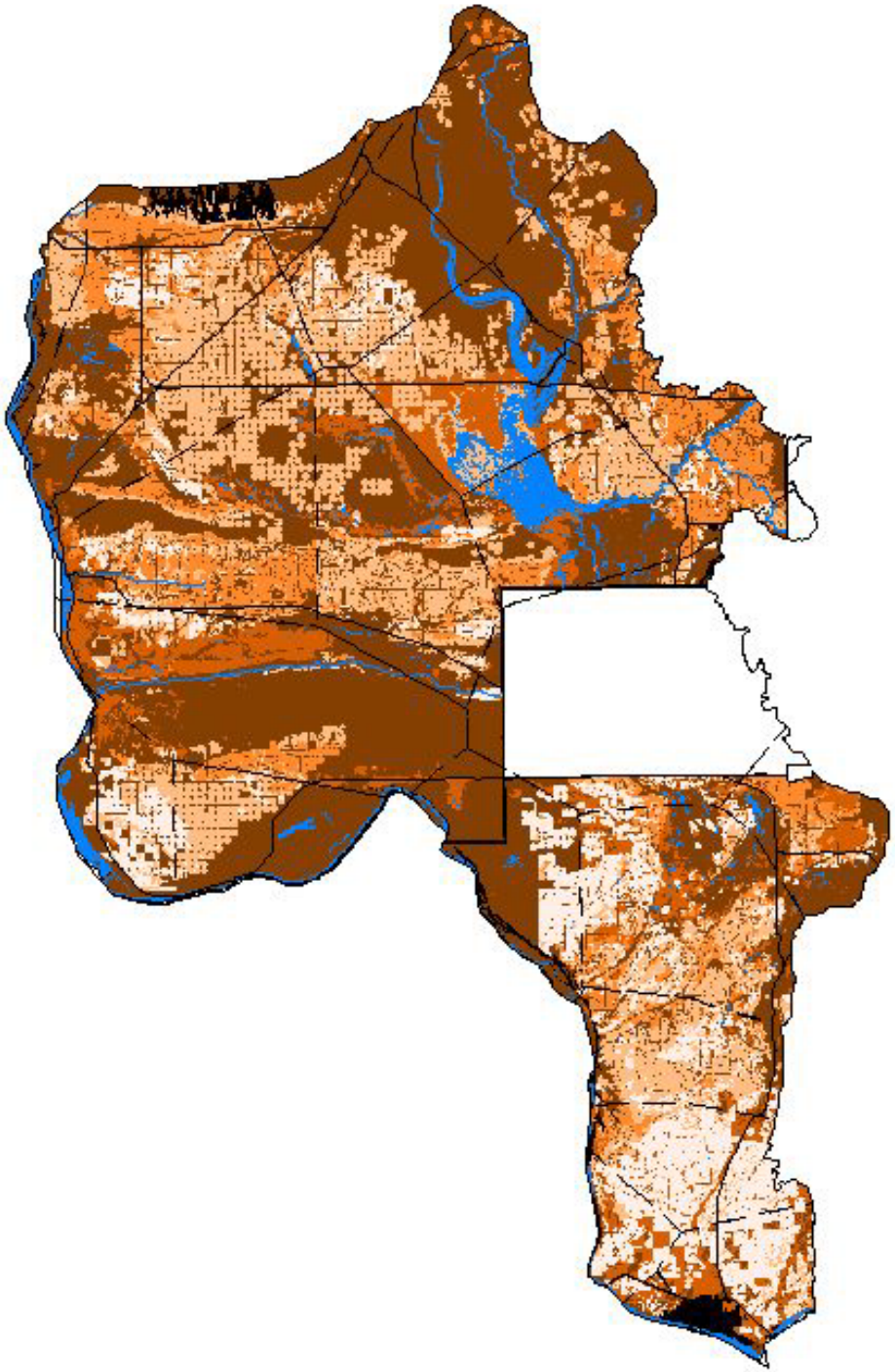
This map shows the model's calculation of the amount of atrazine that theoretically could travel through the various kinds of soils in ten years. It assumes the same amount of rainfall over the entire area, that the ground was all irrigated, and that atrazine was applied at the same rate at the same time everywhere. It keeps these things constant so you can see how the soils differ from each other based on just the soil properties.

The inputs are heavily based on the soil properties from the NRCS county soil survey, so the map reflects soil property patterns in the landscape, as you will see in a subsequent slide.

Remember! Maps from models are not the ground, contain numerous estimates, and must be viewed with a vigorous respect for uncertainty.



This map was produced the same way as the previous map, except that the rainfall was adjusted locally, and irrigation was turned “off” outside of irrigated areas. This area is so arid that the results were in the lowest category whenever irrigation was turned “off” for the model run.



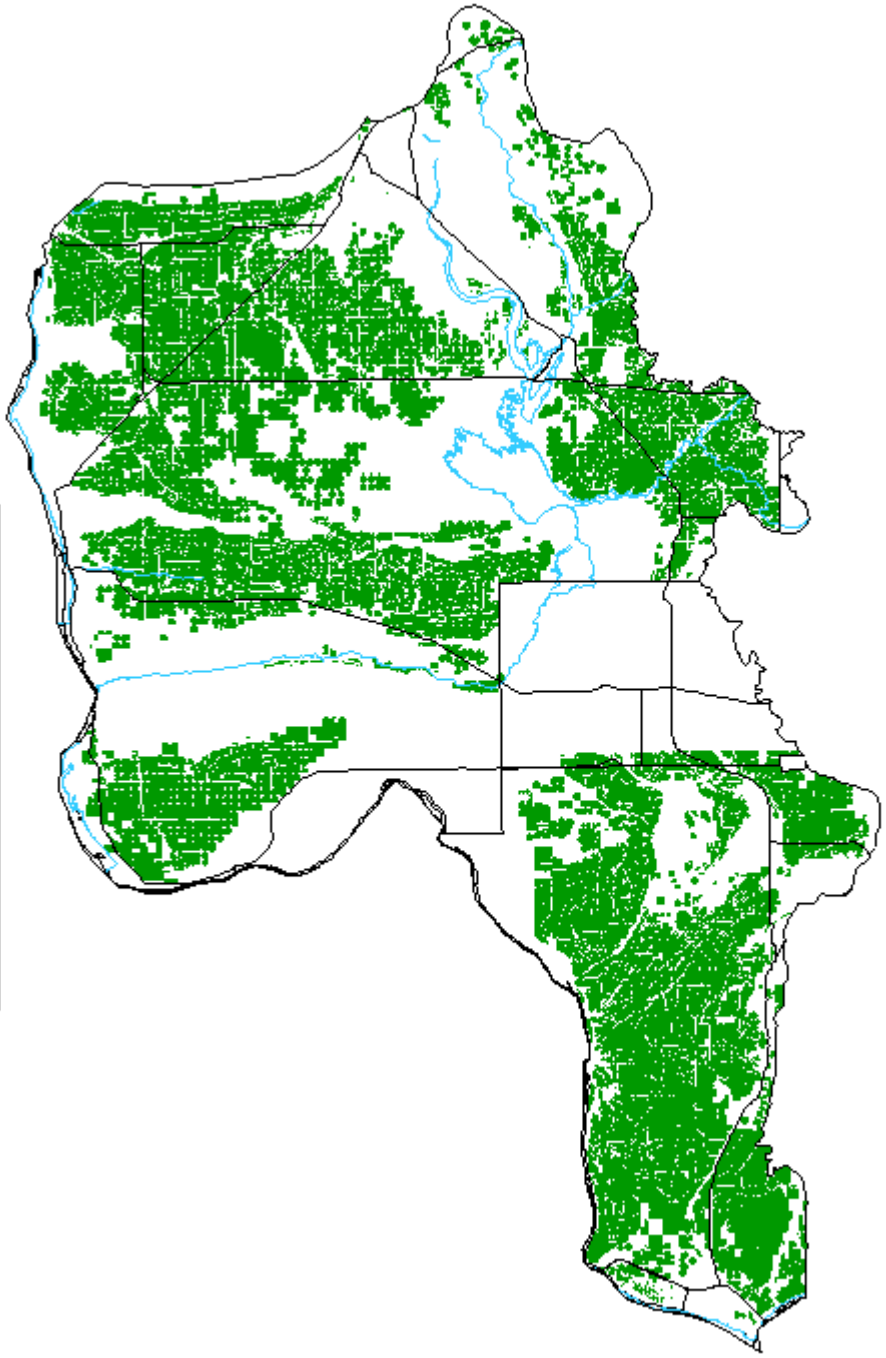
PRZM2 Model Results
Ten-Year Cumulative
Core Flux, Kg/Ha
Monte Carlo 90th Percentile

- **0 - 0.408**
- **0.408 - 1.82**
- **1.82 - 3.64**
- **3.64 - 5.37**
- **5.37 - 8.73**
- **Not Run**

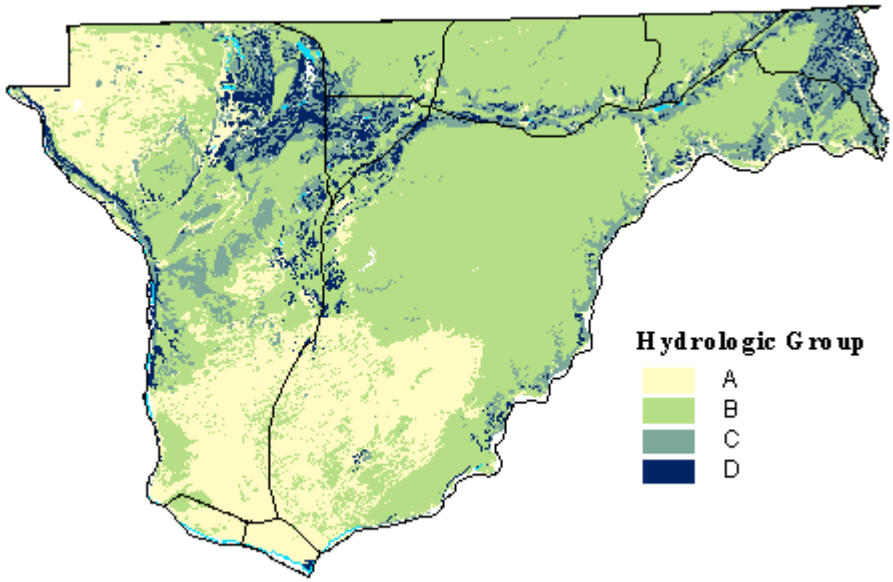
Locally Adjusted Rainfall
Theissen Polygons

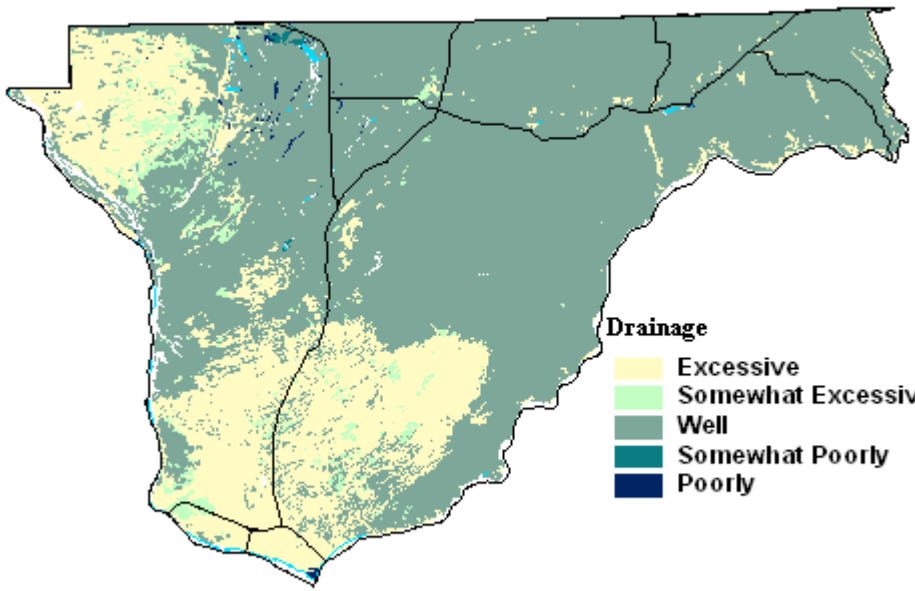
Divisions are according to the ArcView natural breaks for five classes algorithm.

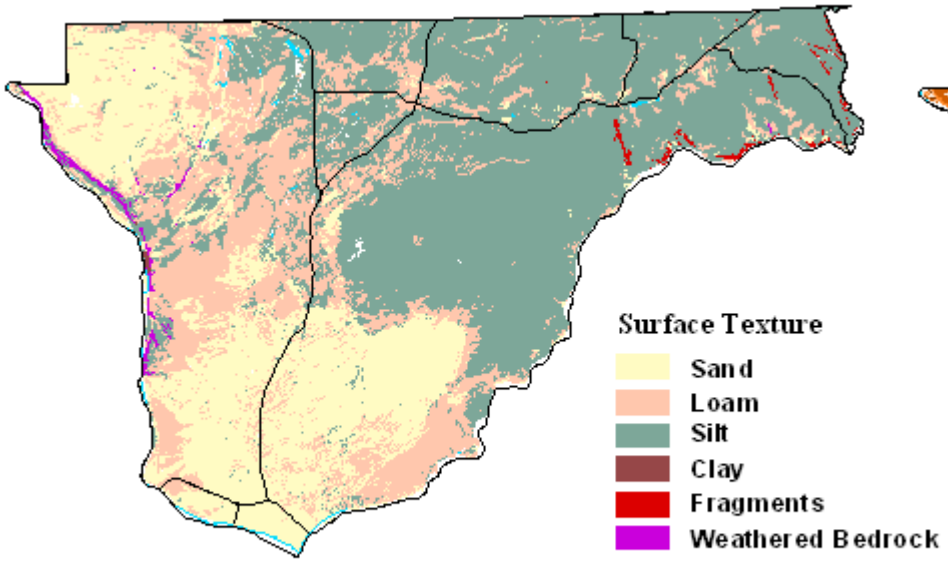
This is a map of irrigated areas from the Franklin Conservation District, digitized from aerial photos. It was used in this pilot project to apply irrigation for the model only in irrigated areas. Unirrigated areas received only rainfall during the model runs.

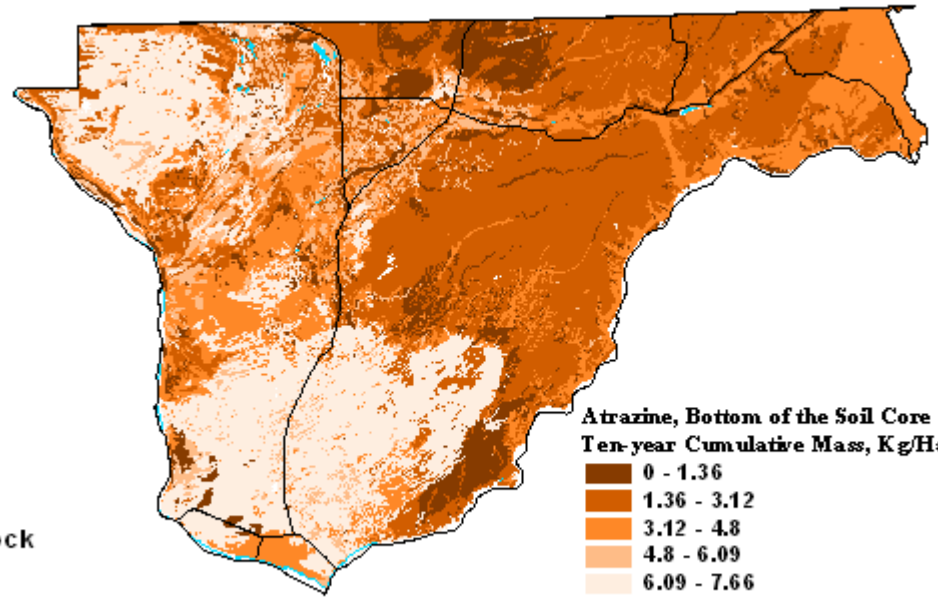


Next: The soil characteristics from the soil survey for Franklin County are shown alongside the PRZM modeling results. You can see the similarity of patterns in the landscape.


Hydrologic Group
A
B
C
D


Drainage
Excessive
Somewhat Excessive
Well
Somewhat Poorly
Poorly


Surface Texture
Sand
Loam
Silt
Clay
Fragments
Weathered Bedrock

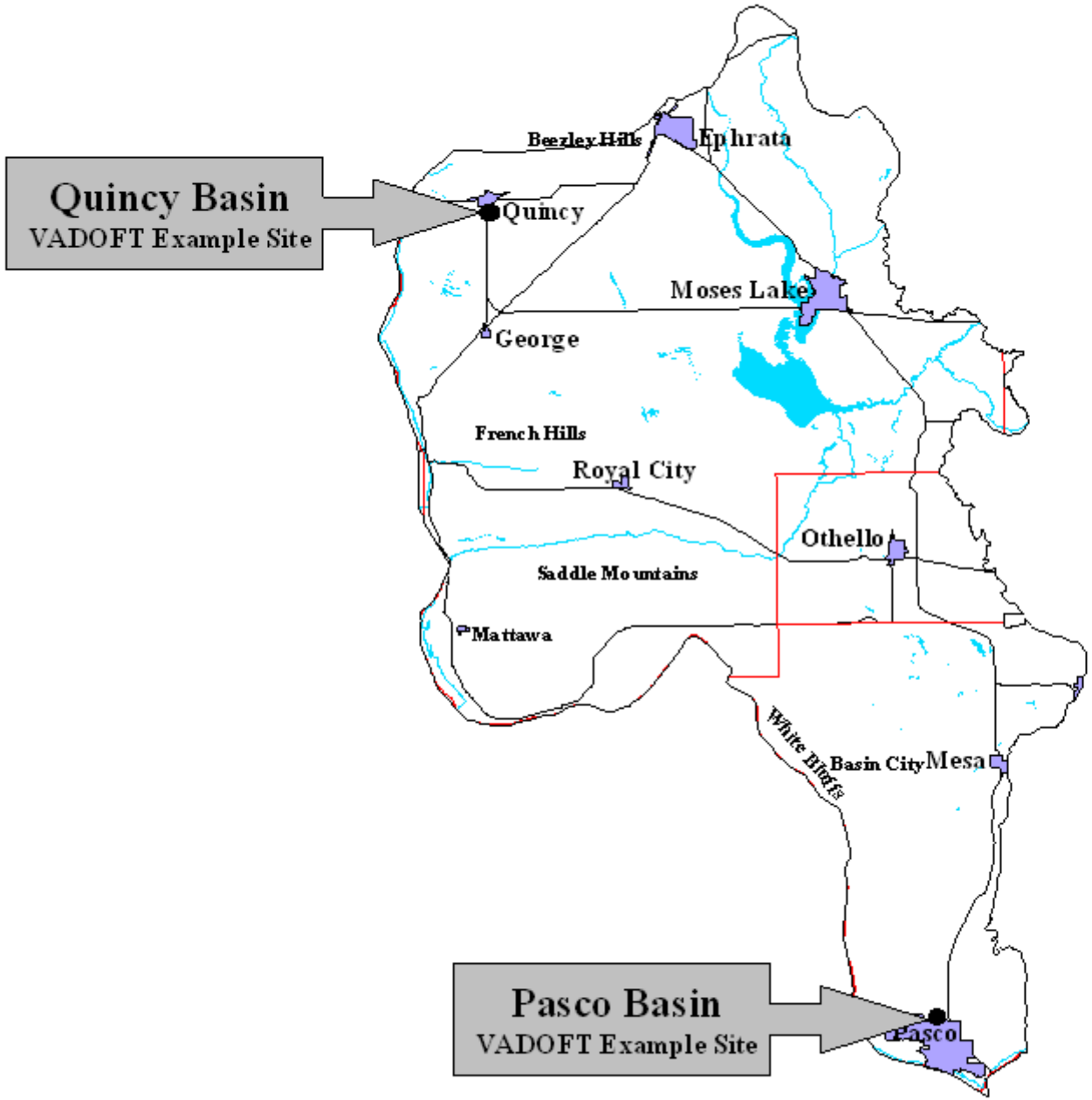

Atrazine, Bottom of the Soil Core
Ten-year Cumulative Mass, Kg/Ha
0 - 1.36
1.36 - 3.12
3.12 - 4.8
4.8 - 6.09
6.09 - 7.66

Next: What about the vadose zone?

Up to now, we have been talking about the soil that extends down to about five feet or so. This is important because the soil is where the pesticide enters the ground, and where much of the natural processes take place that either degrade the pesticide or drive it through the soil.

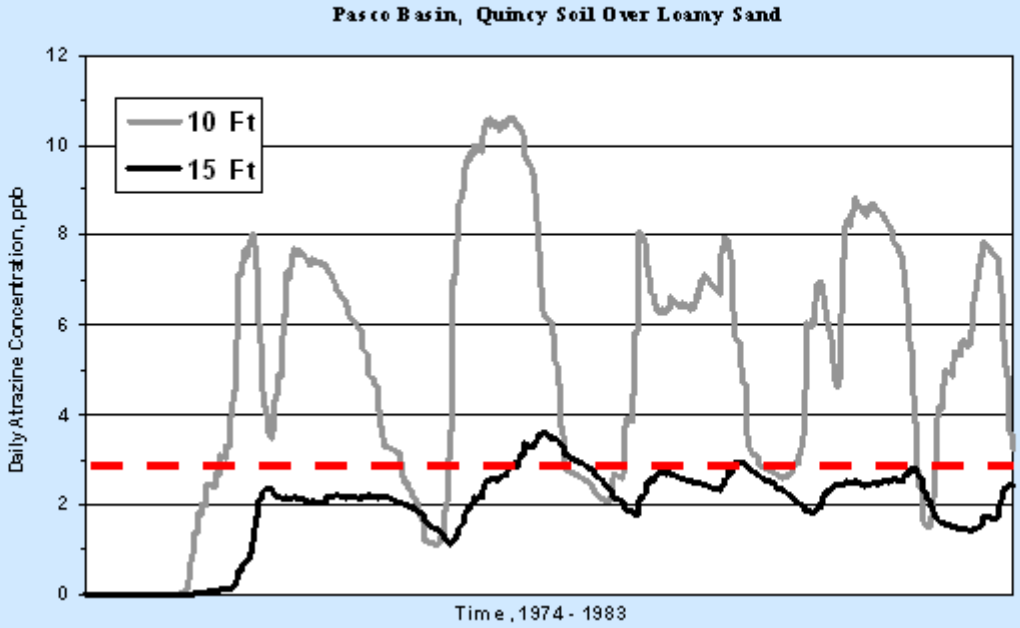
PRZM defines the vadose zone as the portion of the subsurface that is below the soil horizons and above the water table. The layers that make up the vadose zone were deposited at various times in various ways, so that it is very difficult to actually come up with a map of the vadose zone (in contrast to the soil survey which comes with both a map and a database). The best we can do is to look at the surficial geology and some well logs, along with knowledge about how geologic systems work, to estimate very roughly what might be below the soil horizons and above the water table.

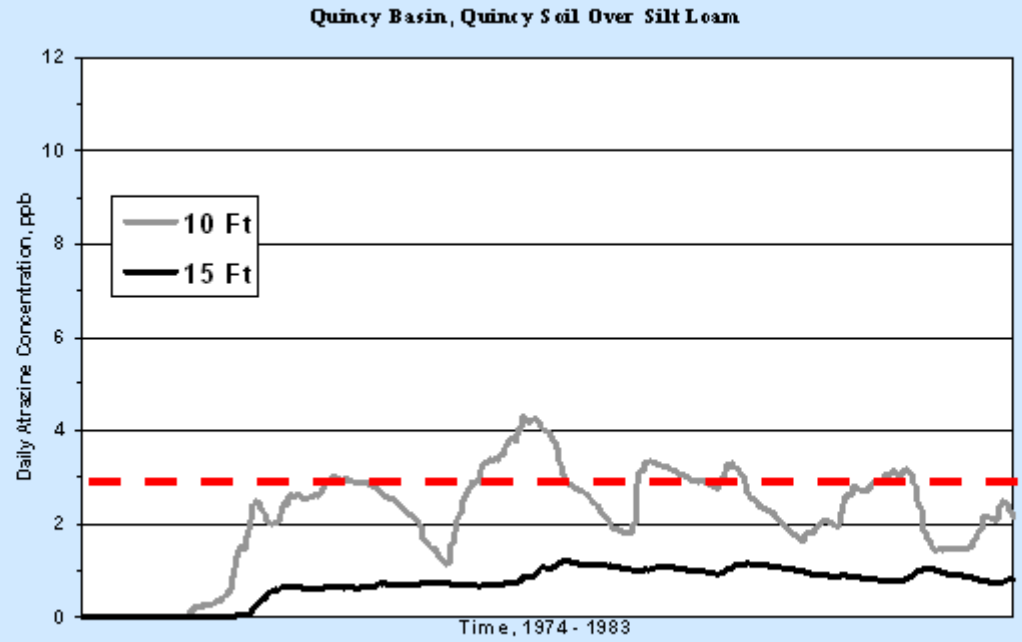
Since trying to analyze the vadose zone for such a large area is beyond the resources available to this project, two trial sites were selected to run the model and explore how the vadose zone might figure into the big picture. To do more, you really would want to map the depth to water very well, and you would want to both analyze well logs and perhaps even apply vadose zone exploration techniques. It's a much bigger project to go beyond modeling the soil horizon.


Quincy Basin
VADOFT Example Site
Beezley Hills
Ephrata
Quincy
Moses Lake
George
French Hills
Royal City
Othello
Saddle Mountains
Mattawa
White Bluffs
Basin City
Mesa
Pasco Basin
VADOFT Example Site
Pasco

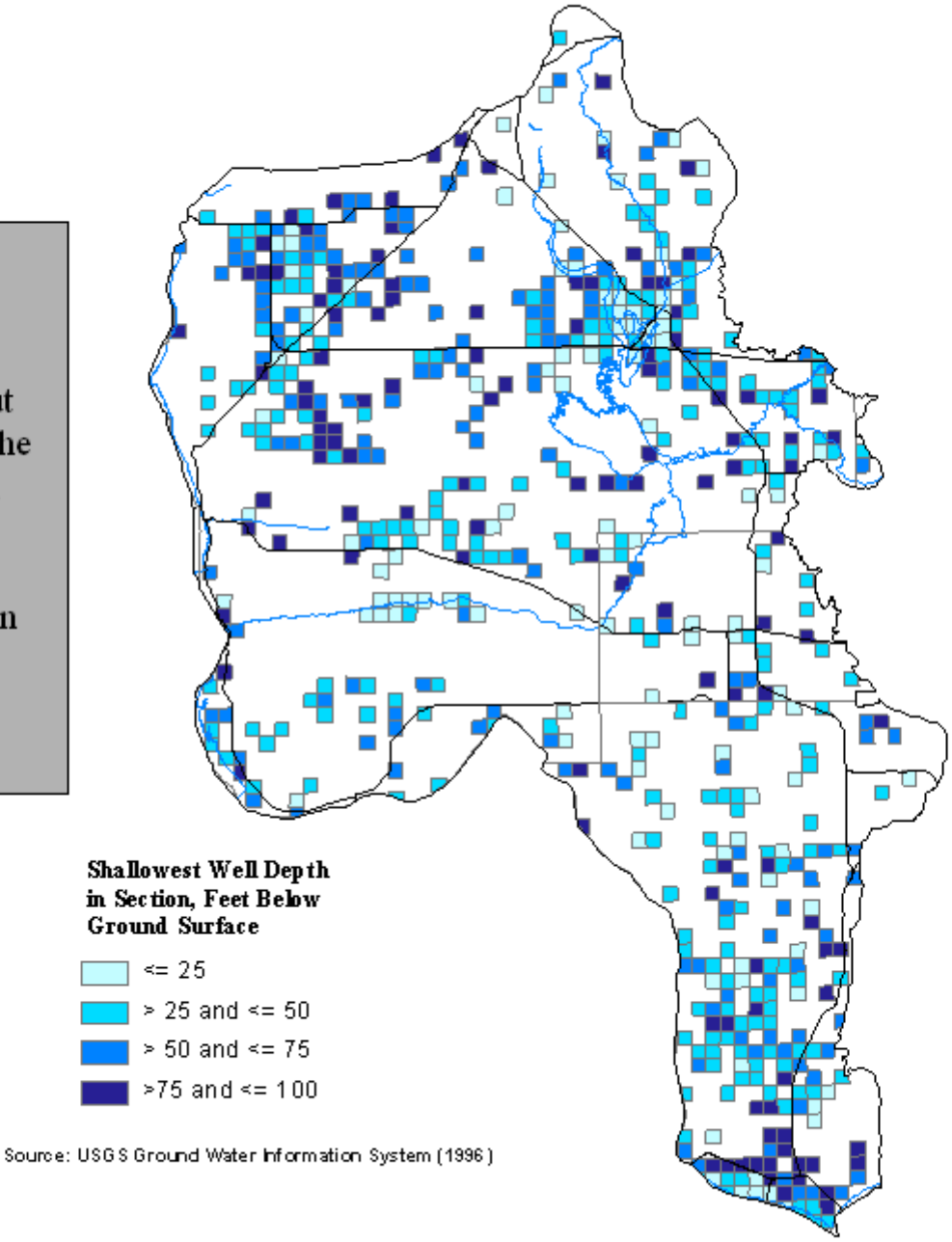
Here is the PRZM/ VADOFT model output for two hypothetical scenarios.

The red dashed line shows where 3 ppb, the EPA Maximum Contaminant Level for atrazine, is on the graph.





Depth to shallow ground water in the Columbia Basin Irrigation Project area isn't well defined, but here is an attempt to use the USGS data for well depth on a section-by-section basis to determine the shallowest ground water in each section. As you can see, the information is incomplete.



Almost the end…

- **The model results are useful for assessing soil characteristics that result in a higher pollution potential.**
- **The model can be used to run “what-if” scenarios.**
- **The model IS NOT the ground. There is uncertainty in the results, because the inputs are measured and estimated. A model of a soil profile IS NOT the soil profile.**
- **We gain insight and information about the soil profile through using the model.**

The End...

- **The results do not directly represent groundwater vulnerability, but soil vulnerability is an important component for ground water vulnerability. We would need better information about the vadose zone and depth to water to bring the results closer to a sort of "true" ground water vulnerability.**
- **The Washington State Department of Agriculture can use the project results and the tools that it provides to further assess the State of Washington with respect to subsurface pollution potential from agricultural chemicals.**